RDT&E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit)								DATE February 1999		
APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA2 Applied Research					R-1 ITEM NOMENCLATURE Extensible Information Systems PE 0602302E, R-1 #13					
COST *(In Millions)*	FY 1998	FY1999	FY2000	FY2001	FY2002	FY2003	FY2004	FY2005	Cost To Complete	Total Cost
Total Program Element (PE) Cost	0.000	0.000	70.000	70.000	70.000	70.000	70.000	70.000	Continuing	Continuing
Deeply Networking Systems AE-01	0.000	0.000	25.000	24.200	12.500	12.000	12.000	12.000	Continuing	Continuing
Software for Autonomous Systems AE-02	0.000	0.000	27.000	26.300	45.500	48.000	48.000	48.000	Continuing	Continuing
Software for Embedded Systems AE-03	0.000	0.000	18.000	19.500	12.000	10.000	10.000	10.000	Continuing	Continuing

(U) Mission Description:

(U) This program is part of a multi-agency initiative to greatly extend the reach and effectiveness of networked computation. It will fund network and software research to facilitate the "deep networking" of computers, such as those embedded within DoD platforms and weapons. It will also conduct research to greatly increase the autonomy of those systems, so as to promote the human role from that of operator to supervisor.

(U) Internet technology targets only 2% of all computers, i.e., the personal computers, servers and supercomputers that are directly responsive to human operators. The remaining 98% of computers are stranded within devices whose sensors and actuators are in direct contact with the physical world. Significant productivity gains will be achieved by extending the “depth” of the network to reach these embedded devices and closing the gap between the disembodied world of command and control systems, and the physical world, which we strive to monitor and control. Similarly today’s interactive software requires the constant attention of human users, who both supply the inputs and consume the results. This program will develop new approaches to software that will allow individual users to leverage hundreds, and eventually thousands, of networked processors.

RDT&E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit)	DATE February 1999
APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA2 Applied Research	R-1 ITEM NOMENCLATURE Extensible Information Systems PE 0602302E

(U) The Deeply Networked Systems project will extend DoD's abilities to monitor and shape the physical environment. Doing so will require a much "deeper" approach to information systems – one that manages the vast quantities of "physical" information that can be accessed by sensors and actuators in direct contact with real world processes. To enable this transition, the network infrastructure must be extended to deal with: a wide diversity of embedded devices dealing in physical world information; vast increases in the numbers of nodes with real-time transmission requirements; and operating regimes in which network-based nodes must host services on behalf of embedded clients.

(U) The Software for Autonomous Systems project develops software to enable reliable, safe, and cooperative operation of free ranging, autonomous systems. This effort includes software for mobile robots (air, land or maritime unmanned vehicles) performing tasks in dynamic, unstructured (physical) environments without the need for synchronous, operator control inputs or high quality communications links. Similarly, this effort includes the development of software agents (knowbots) that can range over cyberspace performing information services, including the capability to negotiate for and assign selected resources. Further, these autonomous systems should be able to learn and adapt to change and uncertainty while improving with experience.

(U) The Software for Embedded Systems project develops a new class of software to deal with the processing of physical world information by networked embedded devices. The convergence of processing power, vanishing size and decreasing cost of today's microprocessors has created new devices and micro sensors that enable a new wave of DoD applications. For example, "smart dust" can be sowed quickly in large quantities in the battlefield to perform new monitoring functions; "smart skin" can be manufactured to conform to mission critical DoD platforms to detect, analyze and generate countermeasure waveform to enemy's radars or sonars; and a host of "Guardian Angel" sensors can be attached to warfighters to autonomously monitor safety and health information.

RDT&E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit)	DATE February 1999
APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA2 Applied Research	R-1 ITEM NOMENCLATURE Extensible Information Systems PE 0602302E

(U) **Program Change Summary:** (*In Millions*)

	FY1998	FY 1999	FY 2000	FY 2001
Previous President's Budget	0	0	0	0
Current Budget	0.000	0.000	70.000	70.000

(U) **Change Summary Explanation:**

FY 2000/01 Increase reflects establishment of a new multi-agency initiative beginning in FY 2000.

RDT&E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit)								DATE February 1999		
APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA2 Applied Research					R-1 ITEM NOMENCLATURE Extensible Information Systems PE 0602302E, Project AE-01					
COST (In Millions)	FY 1998	FY1999	FY2000	FY2001	FY2002	FY2003	FY2004	FY2005	Cost to Complete	Total Cost
Deeply Networked Systems AE-01	0.000	0.000	25.000	24.200	12.500	12.000	12.000	12.000	Continuing	Continuing

(U) Mission Description:

(U) Extending DoD's abilities to monitor and shape the physical environment will require a much "deeper" approach to information systems – one that manages the vast quantities of "physical" information that can be accessed by sensors and actuators in direct contact with real world processes. To enable this transition, the network infrastructure must be extended to deal with: a wide diversity of embedded devices dealing in physical world information; vast increases in the numbers of nodes with real-time transmission requirements; and operating regimes in which network-based nodes must host services on behalf of embedded clients.

(U) The large scale networking of embedded and autonomous devices creates new requirements for: multi-mode network interface technologies that can achieve drastic reductions in costs while being compatible with a wide range of network media; and flexible mechanisms for naming, addressing, configuration and administration that will make the deployment and operation of a hundred billion part infrastructure feasible. These challenges are addressed in the Network Interface component of this project.

(U) Future defense uses of the network will have an increased emphasis on the direct exchange of real-time sensor-derived information among autonomous embedded devices. This reflects a significant change in network traffic from the present environment, which is dominated by the exchange of symbolic information among human users. The new traffic models, architectures and protocols needed to effect this transition will be investigated in the Near Real-Time Networking component of this project.

(U) Many applications of deeply networked systems will perform data dissemination and fusion operations that could most efficiently be performed at nodes within the network. The Agile Network Services component of this project will leverage the capabilities of a programmable network substrate to deploy middleware that is nomadic in nature and can go where network connectivity permits. This capability will permit network elements to host services on behalf of embedded and autonomous devices.

RDT&E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit)	DATE February 1999
APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA2 Applied Research	R-1 ITEM NOMENCLATURE Extensible Information Systems PE 0602302E, Project AE-01

(U) Program Accomplishments and Plans:

(U) FY 1998 Accomplishments:

- Not Applicable.

(U) FY 1999 Plans:

- Not Applicable.

(U) FY 2000 Plans:

- Multi-Mode Network Interfaces. ($ 9.000 Million)
  - Develop laboratory prototypes of efficient multi-mode interface to networks employing diverse link protocols, symbol rates, channel codings, and signaling technologies.
  - Investigate protocols for dynamic configuration of client interfaces.
  - Specify heterogeneous network architecture that integrates wireless, wireline and satellite communication; investigate addressing schemes and routing protocols to support vertical hand-offs across network boundaries.

- Near Real-Time Networking. ($ 11.000 Million)
  - Experiment with time stamping of network payloads in support of performance monitoring.
  - Conduct analysis of network and client nodes to identify key contributors to network latency.
  - Develop new traffic models to analyze impact of sensor generated information on network performance; investigate protocol interactions and cross-talk.

- Agile Network Services. ($ 5.000 Million)
  - Develop framework for automated migration of client specified proxy services to internal network nodes.
  - Investigate techniques for load balancing and service placement optimization.

RDT&E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit)	DATE February 1999
APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA2 Applied Research	R-1 ITEM NOMENCLATURE Extensible Information Systems PE 0602302E, Project AE-01

(U) FY 2001 Plans:

- Multi-Mode Network Interfaces. ($ 7.000 Million)
  - Prototype implementation of network software and application interfaces for multi-mode interfaces.
  - Demonstrate high quality-of-service connectivity among wireless, wireline and satellite networks.
  - Prototype implementation of network architecture for transparent vertical handoffs between different access interface.

- Near Real-Time Networking. ($ 12.000 Million)
  - Specify architectural requirements to achieve order of magnitude reduction in worst case latency induced by packet buffering.
  - Prototype demonstration of sensor/actuator feedback loop operating over near real-time Internet.

- Agile Network Services ($ 5.200 Million)
  - Demonstrate dynamic programmability of selected network components.
  - Develop capability to support the migration of continuously operating client proxy services.
  - Demonstration of agile network services in support of distributed robotics applications.
  - Prototype implementation of middleware services that bridge the gap between logical and physical infrastructure, e.g., by providing and utilizing geo-location information.

(U) Other Program Funding Summary Cost:

- Not Applicable.

(U) Schedule Profile:

- Not Applicable.

RDT&E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit)								DATE February 1999		
APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA2 Applied Research					R-1 ITEM NOMENCLATURE Extensible Information Systems PE 0602302E, Project AE-02					
COST *(In Millions)*	FY 1998	FY1999	FY2000	FY2001	FY2002	FY2003	FY2004	FY2005	Cost to Complete	Total Cost
Software for Autonomous Systems AE-02	0.000	0.000	27.000	26.300	45.500	48.000	48.000	48.000	Continuing	Continuing

(U) Mission Description:

(U) This project develops software to enable reliable, safe, and cooperative operation of free ranging, autonomous systems. This effort includes software for mobile robots (air, land or maritime unmanned vehicles) performing tasks in dynamic, unstructured (physical) environments without the need for synchronous, operator control inputs or high quality communications links. Similarly, this effort includes the development of software agents (knowbots) that can range over cyberspace performing information services, including the capability to negotiate for and assign selected resources. Further, these autonomous systems should be able to learn and adapt to change and uncertainty while improving with experience.

(U) Autonomous Systems will enable revolutionary, asymmetric military capabilities, such as the ability to autonomously convey military payloads (both lethal and non-lethal) to any portion of the battlefield without requiring human operators and the ability to autonomously retrieve, process and deliver information.

(U) The Common Software for Robotics component of this project will develop a software platform that can be reused across a range of experimental autonomous systems.

(U) The Software Enabled Control component will leverage increased processor and memory capacity to vastly increase our ability to maintain control over mobile devices through the development of novel techniques, such as: predictive mode changes, dynamic control scheduling, composable control and dynamic sensor and actuator allocation.

(U) The Negotiation component will enable the autonomous operation of large collections of agents negotiating resource allocation issues, such as those encountered in logistics and countermeasures.

RDT&E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit)	DATE February 1999
APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA2 Applied Research	R-1 ITEM NOMENCLATURE Extensible Information Systems PE 0602302E, Project AE-02

(U) Program Accomplishments and Plans:

(U) FY 1998 Accomplishments:

- Not Applicable

(U) FY 1999 Plans:

- Not Applicable

(U) FY 2000 Plans:

- Common Software for Robotics. ($ 13.000 Million)
  - Develop architecture for integration of deliberative, reactive and learning behavior.
  - Define strategy to account for and integrate emergent behaviors.
  - Identify alternative approaches to software for distributed robotics.

- Software Enabled Control. ($ 9.000 Million)
  - Specify architecture for a hybrid control system that synthesizes the control law approach with computationally-enabled mode logic scalable to very large state spaces of 100K+ states.
  - Develop active transition control and joint mode logic/control law designs.
  - Implement tools for active model creation, augmentation, and query.

- Agent Based Negotiation. ($ 5.000 Million)
  - Develop framework for bottom-up organization of autonomous software.
  - Analyze autonomous software ability to predict, negotiate and track resource requirements under changing environment.
  - Implement software toolkit for knowbot development, generation and deployment.

RDT&E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit)	DATE February 1999
APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA2 Applied Research	R-1 ITEM NOMENCLATURE Extensible Information Systems PE 0602302E, Project AE-02

- Define strategy for tasking and consolidation of responses from large numbers (thousands) of software agents with minimal human intervention.

(U) FY 2001 Plans:

- Common Software for Robotics. ($ 12.000 Million)
  - Prototype implementation demonstrating integration of deliberative, reactive and learning behavior.
  - Laboratory demonstration of compatible knowledge representations for reprogrammable behavior-based control.
  - Prototype demonstration and experimental evaluation of software for distributed robotics capable of coordinating operation of 10+ vehicles.

- Software Enabled Control. ($ 9.800 Million)
  - Alpha-level prototype implementation of multi-mode control architecture and framework.
  - Develop parametric predictive and adaptive control frameworks.
  - Complete multi-level, multi-modal advanced design tools.

- Agent Based Negotiation. ($ 4.500 Million)
  - Prototype demonstration of autonomous software ability to utilize negotiation in logistics scenario.
  - Demonstrate and evaluate software agent's ability to approximate behavior tradeoffs and to utilize negotiation in advanced logistics scenario with a 3-second response requirement.
  - Prototype implementation of negotiation technology in real-time scenario with a 500 millisecond response requirement.

(U) Other Program Funding Summary Cost:

- Not Applicable.

RDT&E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit)	DATE February 1999
APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA2 Applied Research	R-1 ITEM NOMENCLATURE Extensible Information Systems PE 0602302E, Project AE-02

(U) **Schedule Profile:**

- Not Applicable.

RDT&E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit)								DATE February 1999		
APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA2 Applied Research					R-1 ITEM NOMENCLATURE Extensible Information Systems PE 0602302E, Project AE-03					
COST *(In Millions)*	FY 1998	FY1999	FY2000	FY2001	FY2002	FY2003	FY2004	FY2005	Cost to Complete	Total Cost
Software for Embedded Systems AE-03	0.000	0.000	18.000	19.500	12.000	10.000	10.000	10.000	Continuing	Continuing

(U) Mission Description:

(U) This project develops a new class of software to deal with the processing of physical world information by networked embedded devices. The convergence of processing power, vanishing size and decreasing cost of today's microprocessors has created new devices and micro sensors that enable a new wave of DoD applications. For example, "smart dust" can be sowed quickly in large quantities in the battlefield to perform new monitoring functions; "smart skin" can be manufactured to conform to mission critical DoD platforms to detect, analyze and generate countermeasure waveform to enemy's radars or sonars; and a host of "Guardian Angel" sensors can be attached to warfighters to autonomously monitor safety and health information.

(U) Embedded processors interact more directly with the physical world than interactive systems, continuously monitoring changes in their environment through a variety of sensors and controlling their environment through actuators. The large scale networking of such devices creates new requirements for hardware and software components, including run-time systems that facilitate the timely acquisition, processing and exchange of sensor-derived and actuator-destined information.

(U) This project will build on Software and Networking R&D activities, extending and specializing them to sensor networks comprising millions of geographically distributed sensors. A major challenge is the development of software technologies that will allow human beings to retain supervisory control over deeply networked embedded systems, while relieving them of the "in-the-loop" burden associated with traditional interactive computing. The challenge domain for this project will be multi-taskable sensor networks. The sensor tasking, data collection, integration and analysis must be fully automated to enable operation within time constraints far shorter than could be achieved by human operators.

RDT&E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit)	DATE February 1999
APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA2 Applied Research	R-1 ITEM NOMENCLATURE Extensible Information Systems PE 0602302E, Project AE-03

(U) Program Accomplishments and Plans:

(U) FY 1998 Accomplishments:

- Not Applicable

(U) FY 1999 Plans:

- Not Applicable

(U) FY 2000 Plans:

- Common Operating Environment for Embedded Systems. ($ 8.000 Million)
  - Develop methods for distribution and operation of embedded software that allows the C^3I capabilities of embedded devices to be upgraded or altered on a near-real-time basis.
  - Initiate rapid prototyping activities using functional equivalent to target operating environment based on augmentation of COTS technology with capability to originate and host mobile code
  - Investigate suitability of aspect-oriented approaches to specification and generation of embedded systems software.

- Large Scale Networks of Sensors. ($ 7.000 Million)
  - Specify gradient-based approach to automated aggregation and distribution of information from large numbers of multi-taskable sensor nodes.
  - Determine mapping of gradient primitives to multicast and incast network protocols.

- Declarative Tasking and Querying of Embedded Systems. ($ 3.000 Million)
  - Investigate use of declarative interfaces for tasking and querying of networked embedded systems; develop alpha level prototype based on relational database query technology.

RDT&E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit)	DATE February 1999
APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA2 Applied Research	R-1 ITEM NOMENCLATURE Extensible Information Systems PE 0602302E, Project AE-03

(U) FY 2001 Plans:

- Common Operating Environment for Embedded Systems. ($ 7.500 Million)
  - Alpha level prototype of embedded systems operating environment incorporating native support for mobile code and ability to perform in-situ upgrades of all run-time modules.
  - Specify interfaces supporting common run-time services required by signal processing and generation applications.
  - Demonstrate dynamic generation and loading of signal processing applets.

- Large Scale Networks of Sensors. ($ 8.000 Million)
  - Implement experimental prototype supporting automated aggregation and distribution of sensor derived information involving at least 50 nodes and 100 sensors.
  - Demonstrate dissemination of sensor tasking, data collection, integration and analysis over multi-node sensor network spanning tens of square kilometers.

- Declarative Tasking and Querying of Embedded Systems. ($ 4.000 Million)
  - Prototype demonstration using declarative interfaces for tasking and querying of multi-taskable sensor networks.

(U) Other Program Funding Summary Cost:

- Not Applicable

(U) Schedule Profile:

- Not Applicable